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Abstract: To improve the performance of extended enterprises, SMEs must be integrated. This integration must be done on several levels, including the PLM level. PLM is underdeveloped in SMEs mainly because of their difficulties in implementing information systems. This work aims to provide a modelling framework to facilitate the implementation of PLM systems in mechanical SMEs. Our approach offers a generic model for the creation of processes and data models. These models are explained, and then the scope and the improvement they provide are considered.

Keyword: Product Lifecycle Management (PLM); Modelling Framework; Generic Model; Information System

1 PLM in mechanical SMEs

SMEs of the mechanical field have to integrate the different extended enterprises of their customers. This integration is facilitated by the implementation of information systems like PLM that structure and centralize product information. Nevertheless the SMEs do not readily implement these systems [1, 2], while they recognize their usefulness [2].

Recent surveys evaluate the main difficulties in the implementations of PLM systems in SMEs [4, 5]. Combined with previous studies in mechanicals SMEs [6], it results that the main difficulties that arise for the implementation of PLM system for SMEs are:

- The match between the functionalities proposed by the actual software and the needs of some kind of enterprise, especially the raw part makers.
- The difficulty of modelling processes of the company and data model. The

modelling skills are not sufficiently present in SMEs.
- The lack of interoperability between PLM and CAD, ERP and PLM of partner companies.

To solve these problems, section 2 explore existing product models for PLM. Section 3 explains the proposed modeling framework. The first part introduces the global research approach used and the generalization method. The second part presents the generic model obtained before explaining how to use it.

2 PLM models

The product models structure information of the company. The product models support the business functionalities required by SMEs, facilitate the creation of specific models and improve the interoperability of the PLM system with other information systems.

The product modelling has been introduced in Europe in the early 90s by Dupinet [7] and Krause [9], then by Tichkiewitch and Bernard to manage product information in multi-views and multi-actors context [10, 11].

All these models use information, some aimed at structuring information (such as FBS-PPRE [12] and IPPOP [13]), others focus on reuse (patterns, e.g. Gzara patterns [14]), or others focus on exchange (like AP214 [15] or PLCS [16] both from STEP). In the context of PLM systems, these generic models should be adapted. The product models can be used, but they are both too complex and too generic for SMEs.

The use of these models in industrial context requires modifications, adaptations and specialisations. Some works deal with the specialisation and consolidation of generic models, especially STEP [17, 18], but use a top down approach to complete them, and do not fully meet the industrial needs. Others, using a bottom up approach, use frameworks like Zachman [19] or Cimosa [20] to create their own models [21, 22] but they lose the benefit of interoperability of the generic model.

The next section will propose a framework adapted from GERAM [23] containing a bottom up method to get a generic model and a second method to specialize the generic model for a specific domain or company.

3 Modelling framework

3.1 Research approach and generalisation method

To propose a framework that facilitates business processes modelling and business objects modelling by improving the functionalities of PLM and system interoperability, the proposed approach reverses the traditional V cycle (Figure 1). The approach begins with a rising and inductive step formalizing the generic model. Three month of immersions in three representative companies give results for the needs of SMEs about PLM, processes to implement in companies to address these needs and data structure that can automate these processes [24]. These results are then aggregated to create a generic model.

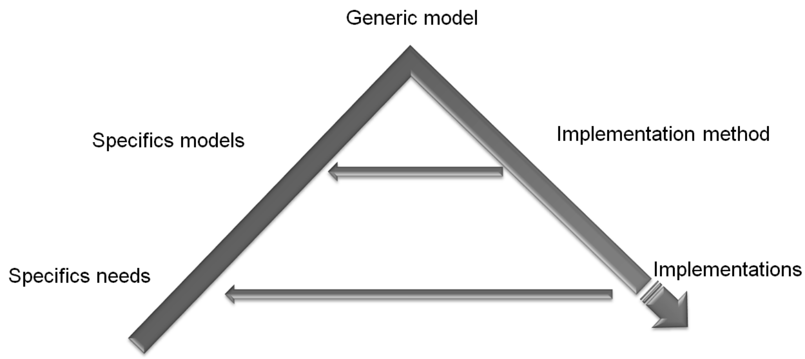

Figure 1 Research approach

To generalise from three specific models to one generic model, the following method is applied:

1. Select the objects that deal with PLM. Indeed the specific models contain specific objects, on the company's business.
2. Group objects by theme and identify generic objects representing each group. This phase is performed by a cognitive analysis of the modeller based on a semantic analysis.
3. Construct generic objects. This step is performed by an extraction of the intersection of attributes and methods.
4. Link the different generic objects. This is done by identifying the various links between specific objects of different groups.

This method is applied on the three specific models to obtain a generic model that could be used in the three representative pilot companies. The next section will explain the model obtained.

3.2 Presentation of the generic model and specialisation method

The different identified objects are activity, product, material, function, resource, trigger, organization and document. The activity specializes in task and operation, the organization in customer and supplier and the resource in material, human and software. They are represented in a UML class diagram (Figure 3).

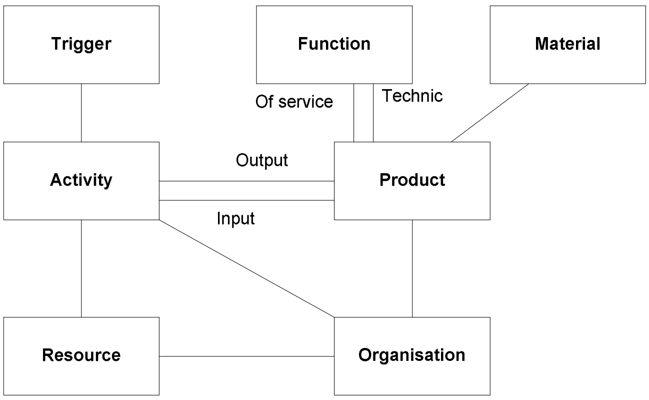

Figure 3 Simplified model

The product model (Figure 4), the activity model (Figure 5) and the resource model (Figure 6) will be explained.

The product is composed of other products, which may be optional. A component can have alternative components in an assembly context. The product has different versions. These versions have states (creation, in validation, validated, obsolete…) and attached documents. The product is linked to the activity through input and output. A product may be the output of an activity and the input of another. The structure of the product by product (assembly) – activity – product (component) decomposition gives different structures depending on the decomposition activity (assembling, maintaining, decommissioning…). The product is also related to the function, as a technical function or a service function via the selected link. A technical function for a component in an assembly becomes a service function for this component when it is alone. This design allows a functional view of the product structure by a decomposition product (assembly) – technical function = service function– product (component).

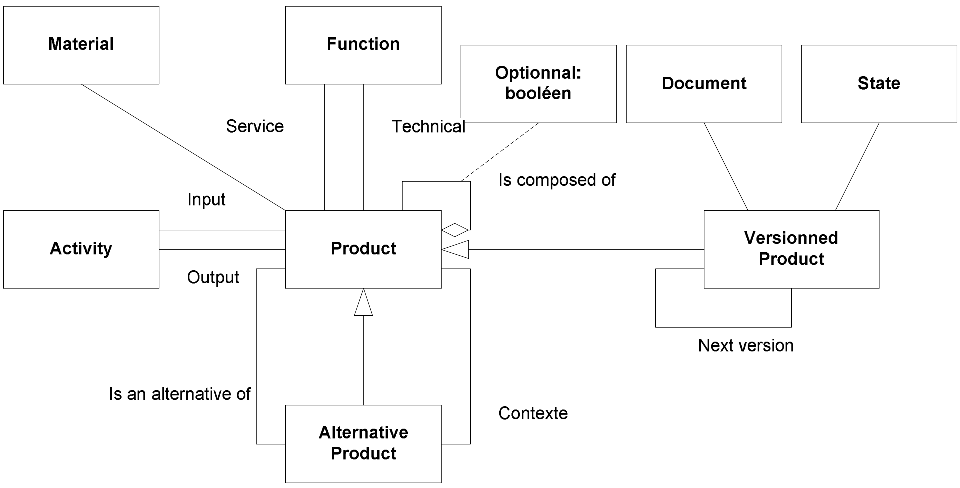

Figure 4 Product model

As the product model, activity has versions that have states and documents. The activity can be composed of other activities which may be optional. Activity can have an alternative activity in a parent activity context (i.e. a process). In addition, the activities are ordered through the link "next activity". A trigger activates this link to go from one activity to the other.

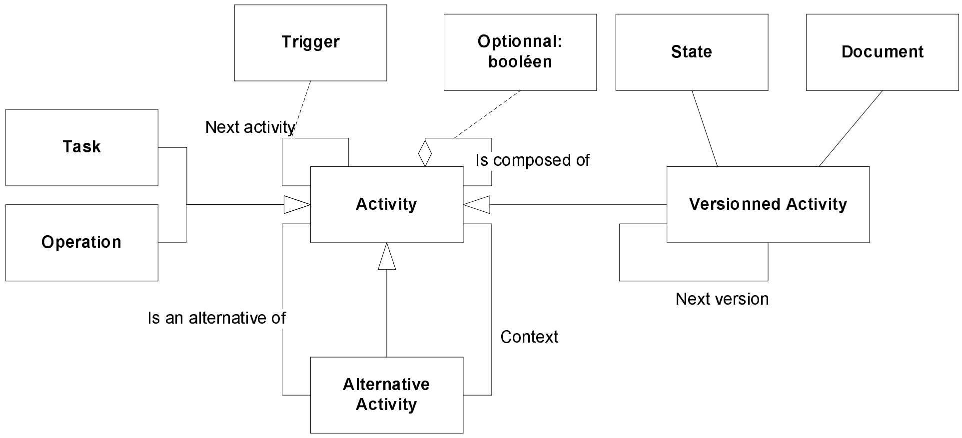

Figure 5 Activity model

The resource has also versions, with states and documents. The resource can be composed of other resources which may be optional. Moreover, the resource may have an alternative resource for a given activity.

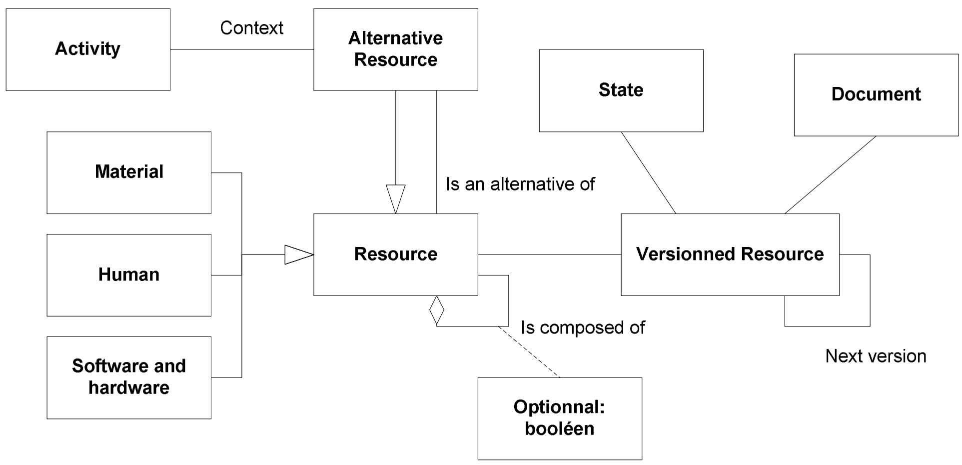

Figure 6 Resource model

Figure 8 shows the framework adapted from GERAM with an abscissa representing the needs, processes and business objects. The ordinate represents the instantiation of components: generic, partial or particular levels. And the depth represents the different views of the system: function, information, resource and organization.

To reach the specific needs of the companies and obtain specific models, the instantiation view specialises the objects of the generic model for each domain and for each company. Three levels are used:

- The generic level: The generic model has been defined in this paper. The objects of this model are generic and can be used in any kind of company.
- The partial level: This model is specialized from the generic model and expresses all the objects of one particular domain, e.g. machining, forging, stamping…
- The particular level: It is the company model. It is defined from the partial model (or directly from the generic model, if the partial model does not exist).

The generic model provides a common point of view of function, information and resource. It also incorporates the organizational aspect which coordinates the other points of views. The representation of the framework could then have only two dimensions, removing the view dimension. But this axis represents the different views that are modelled, even if they are all integrate in the generic model.

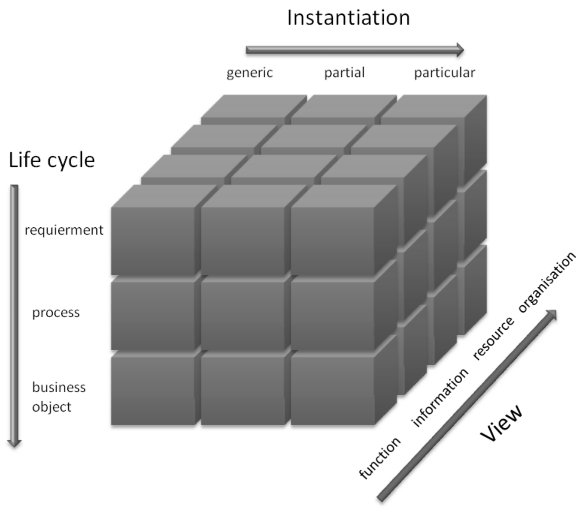

Figure 8 Modelling framework

To create the company-specific models, the proposed method is as follow (Figure 9). It begins with needs analysis then continues with the formalisation of the processes necessary to address these needs. The third step is the extraction of business objects involved in these processes.

1. Identifying needs: Needs identification is made through interviews, observations and immersions in the company. Mind maps are used to formalise the requirements with the experts of the company. This identification is facilitated by the possibility of selecting the generic needs proposed in the generic map.
2. Process definition: Process modelling is done with the experts. IDEF0 diagrams are used to formalise the processes. These processes are deduced

both the needs identified and the corresponding generic processes.

3. Definition of business objects: The identification of objects is done by extracting the inputs and outputs of processes defined in step 2. Based on the generic model, the specialisation of the generic objects leads to specific objects of the company. The UML class diagrams are used to formalise the objects of the company.

All these steps are based on generic models, the difficulty of formalizing the processes and creation of data model for a PLM system is reduced.

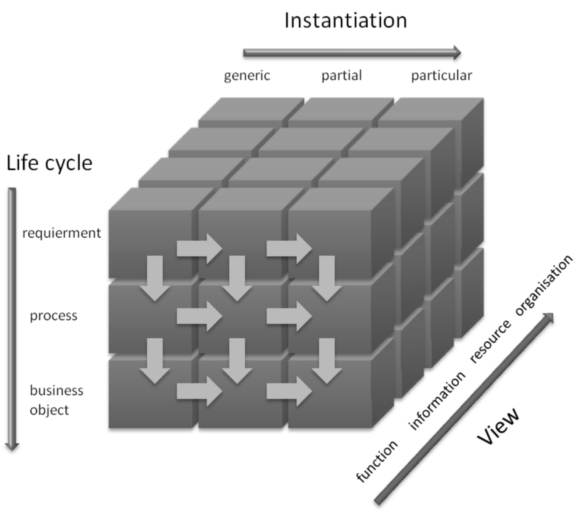

Figure 9 Specialisation of the modelling framework

4 Discussion

The contribution of this work is on two levels: on one hand a method of generalisation of models for a generic model and specialisation of it to particular models and on the other hand a generic model for mechanical SMEs.

The generalization method creates a generic model of various specific models. Different departments or companies may have a common view on their product-process-resource information. The exchange and sharing of information is then facilitated. The difficulty of the method is the grouping of objects that inherit from a single generic object. This is done by a semantic analysis of objects names and attributes, but in the present study, it was facilitated by the fact that the same modeler did the three specific models.

The specialization of the generic model gives a specific model adapted to the business of the company, but keeping the interoperability with other companies around the generic level. The choice of languages for the specialization is done to improve communication with company experts. The elected languages are the mind map formalism to extract requirements, IDEF0 for processes formalization and UML class diagram for the business objects representation. These languages were also used during the modeling phase in the three pilot companies and gives validated results. The use of one language such as

SysML with requirement diagrams, sequential diagrams and class diagrams could be done but we prefer languages already known by the experts.

The second point is generic model for mechanical SMEs that meet needs identified in the three pilot companies. It can be specialized in a particular model for each new company or to each department who need a specific model. The link with the rest of the extended enterprise is provided with the link to the generic model. The main weakness of this model is that it is based only on three cases, even if they are representative.

A PLM demonstrator integrating the approach and the data model has been developed. This demonstrator will be the base of a new product developed by a new society created at the end of the study.

5 Conclusion

The mechanical SMEs need to integrate more and more extended enterprises PLM systems. For interest in PLM system, a framework to facilitate the processes and data modelling and to improve interoperability between their information systems is proposed. This work aims to give them a framework to integrate their functionalities through the specialization of their data model according to their field of activity. It also provides a method of specialization to create their own particular data model ensuring greater interoperability through the alignment of high semantic models (for the PLM) with specialised models for other applications (ERP, CAD and KBS).

The proposed Product Process Resource model is the result of the concatenation of models of three companies representing the needs of mechanical SMEs in terms of PLM. It may be specialized in specific models for each individual company but keeping the same structure for a high level of interoperability.

The next contribution will be using this framework and the generic model to solve the needs identified in mechanical SMEs. It will carry the processes to meet these needs with demonstrator software integrating the proposed framework and the generic model.

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